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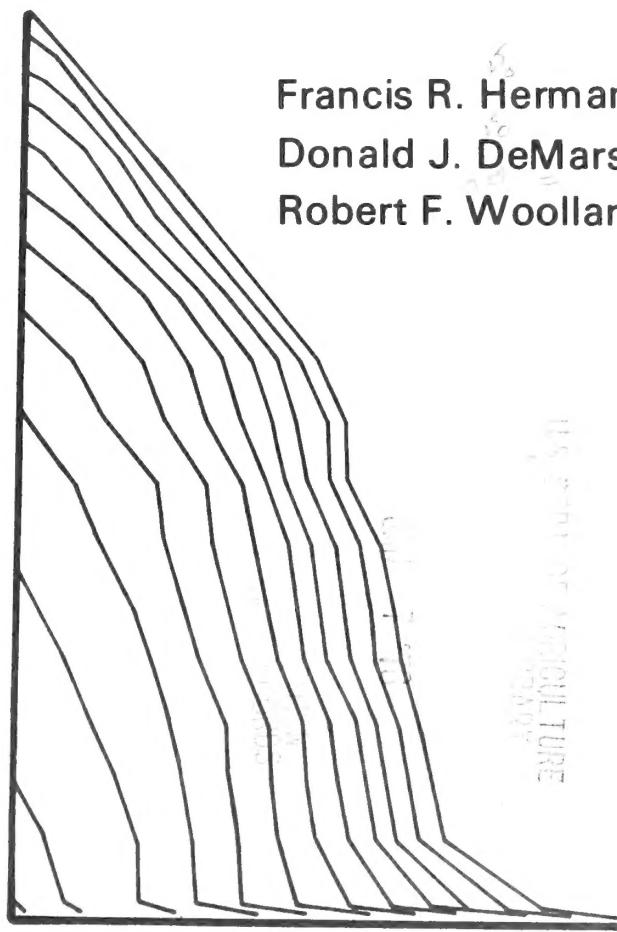
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1975



# Field and Computer Techniques for Stem Analysis of Coniferous Forest Trees

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# FIELD AND COMPUTER TECHNIQUES FOR STEM ANALYSIS OF CONIFEROUS FOREST TREES

## Reference Abstract

Herman, Francis R., Donald J. DeMars, and Robert F. Woollard

1975. Field and computer techniques for stem analysis of coniferous forest trees. USDA For. Serv. Res. Pap. PNW-194, 51 p., illus. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

Field and computer techniques for stem analysis adaptable to both young- and old-growth conifers are presented. Field instructions include a step-by-step explanation of tree cutting, sectioning, ring count, and measurement techniques. A computer program adapted to field techniques reproportions a tree's radial measurement data, calculates height-age-site index information, punches the reproportioned and height-age-site index information on cards, and plots height-age and stem profile graphs. These stem analysis techniques are adaptable to trees of any size up to 800 years old and to either American or metric measures. These instructions enhance the usefulness of the stem analysis research method in obtaining growth information for forest managers.

KEYWORDS: Stem analysis, age determination, ring measurement, data recording methods, old-growth conifers.

## RESEARCH SUMMARY Research Paper PNW-194 1975

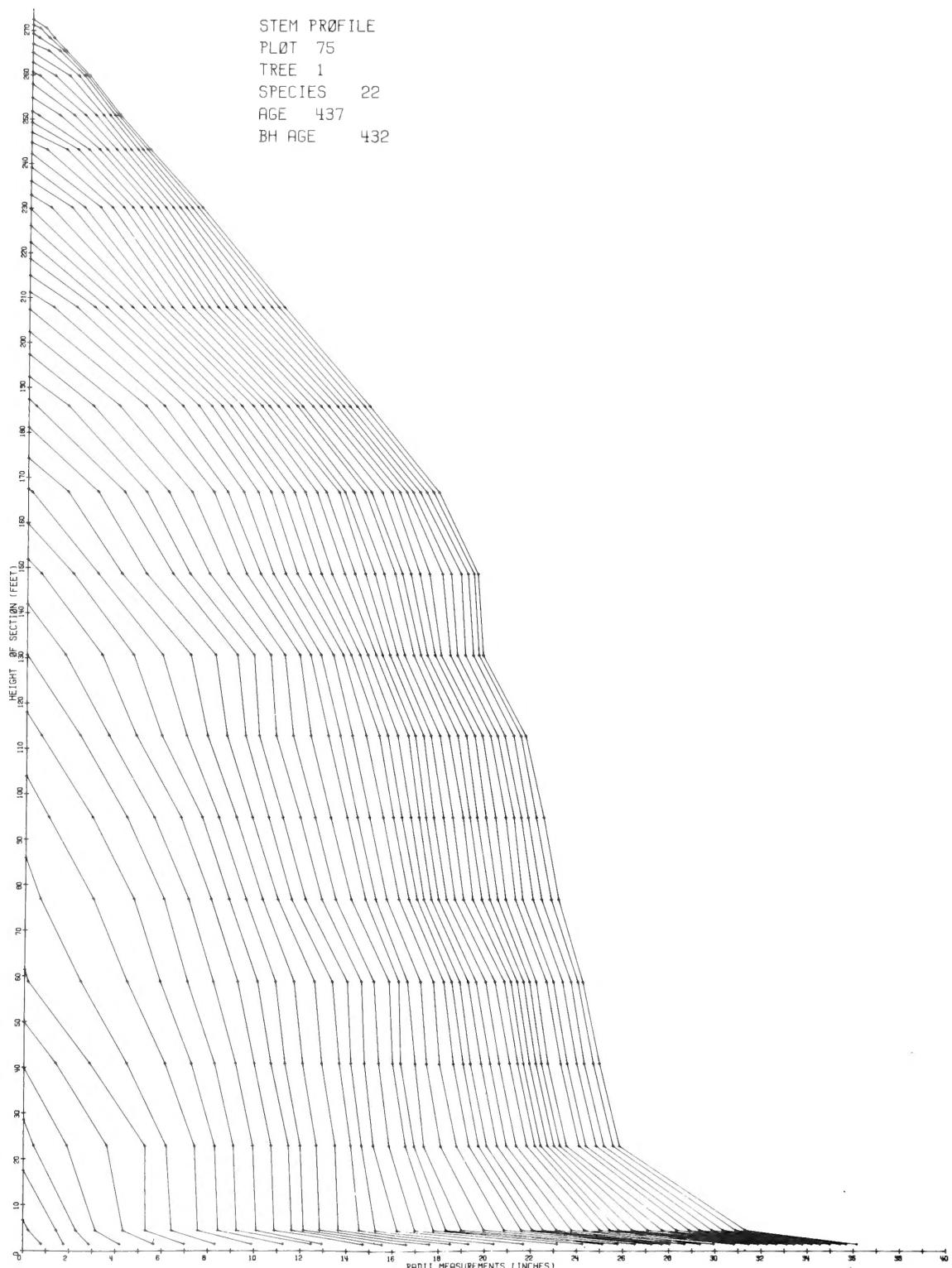
Stem analysis studies within the upper-slope mixed-conifer forests of the Cascade Range in Oregon and Washington were begun in 1965. Objective of these studies was to develop site quality and comparative growth information among the several coniferous species growing in the true fir-hemlock forests. Work was done within the natural range of noble fir between Stevens Pass in Washington and McKenzie Pass in Oregon. Stem analysis was selected as a technique for developing productivity information because it permitted use of overmature trees to obtain information about growth of both young and old trees.

During the course of the studies, efficient methods of data collection and use were devised and applied. From that experience, detailed instructions of stem analysis field methods, including tree felling, sectioning, and measurement of sequential radial growth (SRG), are presented. Three different methods of collecting multiple-ring SRG data are

explained. One method is used as an example to give the reader a complete set of instructions for field collection of data compatible for automatic data processing (ADP). Modification of both data collection and computer programing would be necessary for the other two methods.

Many old and new stem analysis techniques were applied in appropriate succession to develop efficient operations. The goal of these stem analysis techniques is to code and record data compatible for ADP. Output for that ADP consists of reproportioned SRG measurements, stem analysis graph (stem profile chart), and height-age graphs and listings for individual trees. Any or all of the output items may be selected on a single run.

Both field and computer techniques are adaptable to either the American or metric system of measurement--only minor change in programing is necessary for conversion.



*Computer-produced stem profile chart for noble fir  
with a breast-height age of 432 years.*

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## Introduction

To develop site quality and other growth information essential for proper management of the upper-slope true fir-hemlock forests of the Cascade Range in Oregon and Washington, the U.S. Forest Service and Oregon State University began stem analysis studies in 1965. This work was aimed especially at collection of growth data from old-growth noble fir<sup>1/</sup> for estimation of site index (DeMars et al. 1970, Herman and DeMars 1970). Noble fir stem analysis growth data also were used for comparison of methods of site index estimation (Curtis et al. 1974a); and associated Douglas-fir data were used in development of site index information, specifically for upper-slope Douglas-fir in the Cascade Range (Curtis et al. 1974b).

Species composition within the upper-slope mixed-conifer forests of the Cascade Range is complex. Radiolongitudinal data produced from these stem analysis studies are providing the first information about measured growth relationships among surviving old-growth dominant and codominant individual trees within and between defined habitats. With such a wide representation of different species--as many as 9 or 10 on each acre--considerable latitude is available for selection of a particular combination for managed stands. Comparative growth information has proved valuable in other mixed forest types (Deitschman and Green 1965, Green and Alley 1967, Carmean and Vasilevsky 1971) and will prove equally valuable in the Pacific Northwest.

Besides providing comparative growth information specifically for mixed conifers in the Cascade Range of Oregon and Washington, field and computer techniques

presented in this paper are applicable to stem analysis of both young- and old-growth conifers regardless of where they grow. Furthermore, such techniques are adaptable to either the American or metric system of measurement--only minor change in programming would be necessary for conversion.

Natural forest stands containing noble fir are found in the Pacific Northwest Cascade Range roughly between Stevens Pass in northern Washington and McKenzie Pass in central Oregon (fig. 1). The area south of McKenzie Pass in the Willamette National Forest was excluded from the study to avoid confusing growth variation caused by hybridization with Shasta red fir. However, a few Shasta red fir and associated tree species were sectioned for comparative studies in southwestern Oregon. Table 2, appendix I, presents a list of the important upper-slope coniferous tree species with their assigned numerical computer codes.

Because few upper-slope forest stands of 150 years of age and younger were found in the Cascades, older trees were selected for study. Our stem analysis technique permitted us to use overmature trees to obtain information on growth of both young and old trees. Furthermore, stem analysis as a technique was adapted to this growth-evaluation research because no uniform and random range of age classes existed throughout the noble fir range. Except for infrequent, scattered young-growth stands arising from some catastrophic event such as fire or windstorm, most stands were 200 to 400 years old.

The stem analysis approach has the inherent disadvantage of dependence among successive measurements on the same sample tree and presupposes that selected trees were always dominant

<sup>1/</sup> See table 2, appendix I, page 22, for scientific names of trees.

Figure 1.--Stem analysis study locations within the natural range of noble fir in Oregon and Washington.



throughout their lives (Schlich 1895, Dahms 1963). This disadvantage may or may not be important. During our quest for upper-slope noble fir and Douglas-fir site index information, occasional checks of heights of two to four dominant noble fir trees at selected ages at given locations showed no significant changes in dominance.

There are several advantages to the use of the stem analysis method. These have been discussed at length by several workers over many years. Curtis (1964) refers to much of that literature and points favorably toward the use of the method.

The disadvantage of dependence among successive measurements on the same tree can be minor compared with the disadvantages associated with the empirical method of attempting to span a site quality interval for a given species by

selecting for measurement a great many representative temporary forest plots. Stem analysis provides a solution to the problem of unbalanced site selection over a wide range of ages because a uniform number of height observations always is available for any given age for all selected sites.

Even with such widespread species as Douglas-fir (McArdle et al. 1961) and western hemlock (Meyer 1937, Barnes 1962), research workers using stand data were not able to select equal numbers of stands for all ages over an equal number of potential growing sites. Beck and Trousdale (1973) discussed and demonstrated the effect of that problem of disproportional sampling of site and age.

Procedures for stem analysis of trees have been both briefly and comprehensively described in many basic and advanced forestry measurement textbooks and

bulletins at least as early as 1895 (Schlich). A complete description of stem analysis methods and uses in early American forestry literature was presented by Mlodziansky (1898). Detailed field and office procedures included use of such data to determine past and current volumes of individual trees. Many other references to early American forestry stem analysis methods and uses are given by Spurr (1952) and Turnbull.<sup>2/</sup> Later references to the technique and one of the most complete contemporary descriptions of procedures are contained in a mensuration text by Husch (1963).

Our paper describes for the first time detailed and complete procedures, including collection of field data and use of that data, for stem profiles and height-age curves produced by Automatic Data Processing (ADP).

Objectives of this paper are:

1. To describe the field and laboratory procedures actually used in stem analyses.
2. To recommend field and laboratory procedures applicable to similar studies and forestry education exercises.
3. To present a stem analysis computer program with instructions for its use.

Techniques of field, laboratory, and computer operations presented in this paper are purposely detailed to furnish step-by-step instructions for those who wish to use our stem analysis procedures to develop site index information and secure stem profile data for growth comparisons and volume determinations.

<sup>2/</sup> Kenneth J. Turnbull. Stem analysis techniques and applications and some studies of second-growth Douglas-fir in western Washington. Unpublished M. F. thesis, University of Washington, Seattle, 1958.

## Stem Analysis Field Methods

Hundreds of true fir-hemlock stands within the natural range of noble fir were visited. From these stands, study locations were selected. Habitat type and understory vegetation differentials<sup>3/4</sup> at varying elevations and latitudes were bases for selection. Frequently, site continuums were selected--as from ridgeline to valley bottom.

### TREE SELECTION AND PREFELLING MARKING AND MEASUREMENTS

After each location was determined, the tallest dominant or codominant tree of each species (table 2, appendix I) present within approximately one-fourth acre was selected for stem analysis. Trees with obvious defects such as thin crowns, stag, forked, or broken tops, and bent and crooked stems were avoided, as were severely leaning or unbalanced trees. Rot indicators such as conks, catfaces, frost cracks, and abnormal stem swelling caused trees to be rejected. Any tree suspected of decay was "bored" at stump height with the rounded tip of the chain saw. Expelled wood fragments were monitored for rot. Trees with "brooms" in the crown, whether caused by dwarf mistletoe or some other disease, were taken if nothing else was available.

After trees were selected and before they were felled, they were circumscribed at stump and breast heights with spray

<sup>3/</sup> Jerry F. Franklin. Study plan for development of a habitat type classification of the true fir-hemlock forests of the southern Washington Cascades. 51 p. Unpublished report, Forestry Sciences Laboratory, Corvallis, Oregon, 1962.

<sup>4/</sup> Jerry Forest Franklin. Vegetation and soils in the subalpine forests of the southern Washington Cascade Range. Ph. D. thesis, Washington State University, Pullman, 132 p. 1966.

paint, in planes at right angles to the vertical axes of stems. Stump and breast height diameters were measured with a diameter tape. Where information about stem cross-section eccentricity in relation to cardinal direction was desired, special stump and breast height stem marks were made before trees were felled. North and south (or east and west) cardinal direction stem exposures were marked with vertical spray paint lines (fig. 2). Analyses of cross-section

## TREE FELLING

Where possible, felling was done along contour--not over drainages or rock outcrops--to avoid excessive breakage. Felling into adjacent trees was avoided as much as possible to prevent hangups, severe breakage, and loss of candidate treetop. Stands with hemlocks were especially difficult to work within because the long crowns easily became entangled.

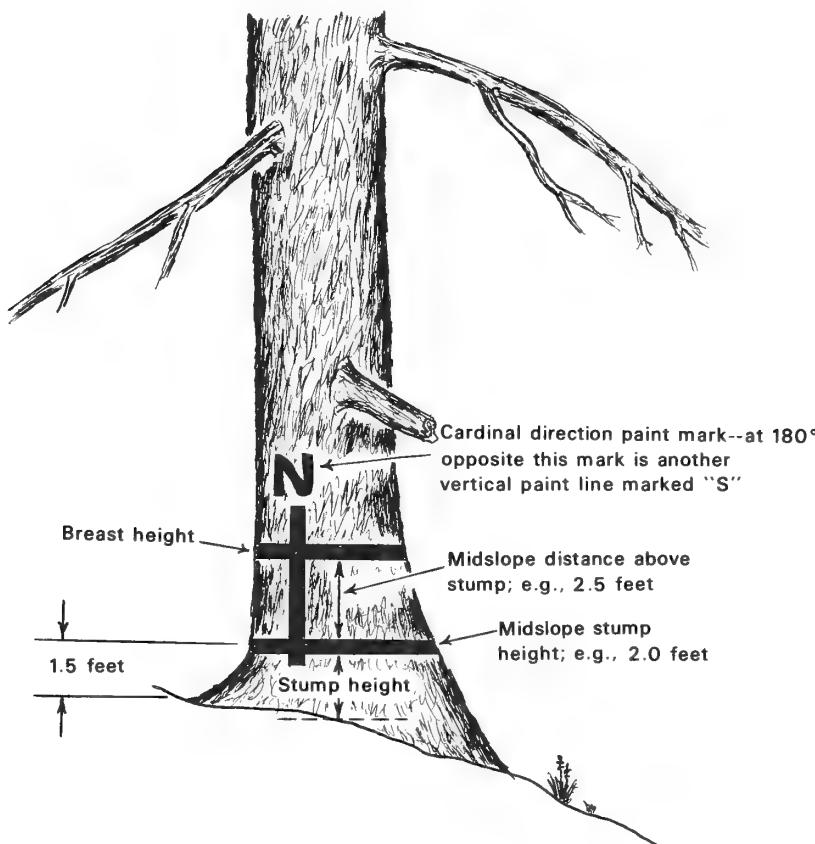


Figure 2.--Diagram showing painted stump ring, breast high ring, and cardinal direction, or exposure reference marks.

eccentricity information are made separately from the same ring count and ring interval measurement data collected for height-diameter and height-age growth evaluations.

The stump was cut either 2 inches above or 2 inches below the stump ring mark, with care taken not to undercut across the stump mark. If the cut was below stump mark, the undercut left a flat surface on

base of upper stem section. If cut was above stump mark, the undercut left a flat surface on stump. The stump section was prepared for measurement by cutting through the painted ring. When slightly leaning or unbalanced trees necessarily were selected, special care in stump preparation was taken to avoid pulling long splinters of wood from the stem or stump. Back cut was always maintained parallel to undercut. Side cuts were made to prevent longitudinal "barber chair" splitting of the stem.

### **TREE STEM REASSEMBLY AND MEASUREMENT**

The tree was limbed from stump to top, including all broken stem parts. Before length measurements were taken, all broken stem pieces were matched to provide accurate information on stem length. Broken bark and wood patterns, wood grain patterns, and knot arrangements provided "keys" to accurate "reassembly." Broken pieces quite often were impossible to physically join together because of weight and displacement distances. Pressurized spray paint cans with a fine nozzle provided a good method of marking matching points on broken stems.

### **TREE SECTIONING**

All points on tree stem where sectioning cuts were to be made were marked with paint. Cuts were made at short log length intervals so they could be salvaged. Although actual measurements varied, the most satisfactory sectioning sequence for both salvage and good stem profile data was: stump height, 4.5 feet (1.37 meters) above ground (breast height); 9 feet (2.74 meters) above b.h.; then 18 feet (5.47 meters); 36 feet (10.94 meters); etc., by 18-foot (5.47-meter) increments to a 12-inch (30.5-centimeter) top. Sectioning above the 12-inch top

was done at shorter intervals--6 to 10 feet (1.8 to 3 meters)--preferably centered near selected internodes. Where salvage of stem was not required, section cuts above breast height were made at individual discretion, but at *no* greater intervals than where salvage was planned. In addition to the sectioning points, cuts made at a point just below the base of the primary live crown in an area undistorted by branch swell provide information on stem form below and within the crown.

Section cuts were marked by use of a 100-foot steel tape graduated in feet and hundredths of feet. Average stump height was measured and zero end of the tape was placed at base of cut stem (allowing for the width of the stump section if taken from base of stem). Cumulative measurements of stem length were carried as shown in figure 3. Several methods of measuring length were tried. All were discarded in favor of the system shown in figure 3. Best accuracy and, of course, fewer rechecks of down trees were necessary when the cumulative-height-above-stump measurements were obtained before the stem was bucked and sectioned. Bucking of the stem before stem length and diameter measurements are taken is best avoided.

Yellowjacket Creek  
North Bend Ranger District  
Snoqualmie National Forest

①

Noble Fir ④ Plot 75 ③  
Established 6/28/68 ⑤  
Felled 8/11/68 ⑥

Taped Section Intervals	Stump Height and Cumulative Height Above Ground	Diameter Outside Bark ⑫	Diameter Inside Bark ⑬	Single Bark Thickness Measurements						Remarks
				Feet	Feet	Inches	Inches	-	-	
Stump	⑦ 1.5	74.9	* 72.30 ⑯	-	-	-	-	-	-	Ave 1.30
B. H.	3.0 ⑧	65.8	* 62.66	1.20	1.30	1.40	1.05	1.50	1.35	Ave 1.57
21.4	21.4	54.1	51.75	1.75	1.55	1.15	2.10	1.40	1.45	
39.4	39.4	52.4	50.05							
57.3	57.3	50.5	48.60							
75.4	75.4	48.6	46.50							
⑨ 93.4	93.4	47.5	45.20							
⑩ 18.0	111.4	46.6	43.60							
32.0	125.4	Break ⑪								
3.8	129.2	43.1	* 39.86 ⑯	1.80	1.80	1.70	1.50	1.40	1.50	Ave 1.62
21.8	147.2	* 42.42 ⑬	39.40	1.40	1.50	1.55	1.95	2.15	2.20	Ave 1.79
39.9	165.3	38.8	36.00							
46.8	172.2	Break								
12.2	184.4	* 33.14 ⑯	29.90	1.65	1.85	1.60	1.50	1.55	1.55	Ave 1.62
29.1	201.3	Break	22.36							
5.1	206.4	25.1								
13.3	214.6	Break								
3.9	218.5	Break								
10.2	228.7	* 17.66 ⑯	15.10	1.20	1.25	1.40	1.25	1.25	1.35	Ave. 1.28
17.0	232.5	Break								
6.8	239.3	Break								
2.4	241.7	12.14	10.45							
10.1	249.4	9.12	7.80							
12.8	252.1	Break								
4.9	257.0	Break								
1.3	258.3	5.90	5.06							
5.9	262.9	Break	2.93							
1.1	264.0	3.35								
2.9	265.8									
4.0	266.7	2.14	1.85							
4.6	267.5	Break								
1.6	269.1	1.37	1.18							
2.3	269.8	Break								
1.3	⑯ 271.1	Tip								
⑯ Elevation			2903 ft							
⑯ Slope	10 %	Aspect ⑯	SE							
⑯ Clear length			121.5	ft. above stump						
⑯ Length to main live crown			121.5	ft. above stump						
⑯ Length to epicormic live crown			121.5	ft. above stump						
⑯ Crown position			Dominant							
⑯ Total height			273.6 ft							

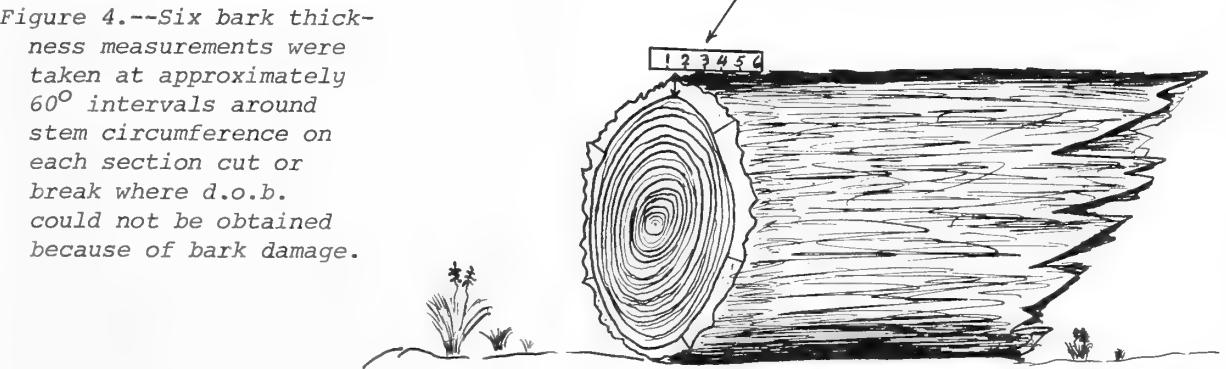
\* Measurements in shaded circles are calculated--not directly measured.

Figure 3.--Sample of field notes taken in waterproof field surveying book for tree measured before it was sectioned.

## Explanation of Field Notes (fig. 3) 5/

1. Plot name--from some local geographic feature or manmade structure such as Lower Cedar River, Humpback Mountain, Yellowjacket Creek, Carpenter Lookout Road, etc.
2. District and Forest.
3. Plot number.
4. Species and tree number.
5. Tree selection date.
6. Tree felling and sectioning (bucking) date.
7. Stump height above average ground level--stump cut was made 1.5 feet above ground on uphill side. However, *recorded* stump height above average ground level was at least equal to 1.5 feet. Usually it was greater because of sloping ground.
8. Cumulative stem length from zero (stump cut).
9. Tape "zeroed" at sectioning point, 93.4 feet above stump. If tape longer than 100 feet is used, "zeroing tape" usually is not required unless stem is broken.
10. Cumulative stem length from tape zero at 93.4-foot section.
11. "Break"--stem is broken at "32.0'" from "93.4" tape zero point. Tape is "zeroed" again and cumulative measures continued to next stem "break," etc.
12. Diameter outside bark (d. o. b.) for stump and breast height obtained before tree was felled, and upper stem diameters obtained where bark was undamaged before felled stem was bucked.
13. Where bark was damaged at planned point of sectioning, d. o. b., where circled, was calculated; double of average of six bark thickness measurements was added to the peeled diameter of section. Measurements of bark thickness were taken at approximately 60° intervals on the adjacent, undamaged section cut and/or break. Each bark thickness measurement represents the thickest bark within that 60° arc on the stem at or near the section point. Where end of cut stem was used, a 6-inch rule was used to project undamaged bark surface to cut stem surface for measurement (fig. 4).

Figure 4.--Six bark thickness measurements were taken at approximately 60° intervals around stem circumference on each section cut or break where d.o.b. could not be obtained because of bark damage.



14. Diameters inside bark (d. i. b.), except where circled, were obtained by "slipping" bark from stem section. This is easily done during the early part of the growing season and soon after felling. Later in the growing season, all bark thickness was measured as described in point 13 because bark could not be easily and completely removed.
15. Diameters inside bark, where circled, were calculated as described in point 13 from double of average of six bark thickness measurements subtracted from d. o. b.
16. Total stem length above stump.
17. Plot elevation from barometric altimeter.
18. Average slope of plot area in percent.
19. Aspect expressed in quadrant or half-quadrant.
20. Clear length above stump--no limbs or knot indicators on bark to point specified. Small epicormic branches 1/4-inch or less in diameter were ignored in determination of clear length.
21. Length to base of live crown above stump--this is to base of primary or main live crown exclusive of all green epicormic or dead branches.
22. Length to base of live crown above stump as defined by beginning of epicormic branches often found on Engelmann spruce and occasionally Douglas-fir.
23. Crown position--"Dominant," "Codominant," etc.
24. Total tree height above average ground level. Each tree selected and felled for stem analysis provided its own individual measurement problems. Not all of the previously described measurement techniques necessarily were used on each tree. In practice, the most efficient combination of measurement techniques that provided accurate data was selected and applied as needed.

## DETAILED SECTIONING MEASUREMENTS, RING COUNTS, AND SEQUENTIAL RADIAL GROWTH MEASUREMENTS

1. Before actual sectioning:<sup>6/</sup>
  - a. Diameter outside bark was measured at all designated sectioning points. Where bark was damaged or lost, diameters outside bark were taken at equal distances both ways along log from the section cutting mark and averaged (except at stump and breast height). When this distance was greater than twice the diameter at that point, the section d. o. b. was obtained by d. i. b. measurement and individual bark measurements from logs adjacent to section. (See explanatory information relative to fig. 4.)
  - b. Cardinal direction upper-stem exposure marks (see fig. 2). Whichever felled stem exposure faces skyward--north, east, south, or west--dictates position of exposure reference marks across all felled stem section points before stem is bucked and sectioned. If tree is bucked before exposure marks are made, this information quite likely will be impossible to collect.
2. Sectioning:

Cross sections (disks) 2 to 3 inches thick were cut at all marked stem section points where diameter was larger than 20 inches (fig. 5). Disks

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<sup>6/</sup> If faller worked when measurement crew could not be present, many measurement problems arose. Trees were felled and bucked to length and transverse sections were cut before outside bark diameter and cumulative height measurements were taken. Inaccuracies in diameter and length measurements taken by untrained personnel negated efficiency otherwise derived. However, this type of assembly line production can be used if felling and bucking crews are *carefully* trained.

*Figure 5.--Cutting stem section disk from old-growth Douglas-fir.*



1 to 2 inches thick were taken from smaller diameter stem sections. Bark was removed completely for d.i.b. measurement. When only a partial section was available because of breakage or bucking difficulties, its diameter was estimated from other associated measurements. A partial section was only acceptable when it contained the pith and a complete radius with an acceptable or "representative" (reasonably normal) ring-growth pattern.

Trees having annual ring pattern destroyed by rot, of course, were rejected. However, where decay was encountered that had not completely obliterated the annual rings, thicker sections of 4 to 6 inches were cut. Decayed sections were carefully handled to prevent breakage. Sandwiching them between strips of 1/4-inch plywood eliminated breakage and loss of information. These later were carefully soaked in water and frozen to facilitate ring counts and measurements

(Herman et al. 1972a, 1972b). Douglass (1928) described an efficient field technique which used a paraffin-gasoline solution to render decayed wood workable. His technique permitted immediate ring counts and sequential radial growth measurements.

3. Recommended ring counts and sequential radial growth measurements (fig. 6):

If single ring counts and measurements are to provide data for stem profiles, data collection is relatively uncomplicated. However, if decadal, half-decadal, or other multiple ring measurements are to be taken, counts and sequential radial growth measurements must be taken in a specific manner to provide type of data desired.

At least three different approaches to multiple ring counts are possible:

- If desirable to compare tree growth



Figure 6.--Ring counting using large reading glass.

of several trees at selected years in fixed sequence, multiple-ring count must begin at each section circumference and proceed toward the pith. After ring count is completed and ring intervals are marked for each section radius, sequential radial increment measurements are made from the pith and recorded on stem analysis ADP coding form (fig. 11, appendix I). For example, for a tree cut in 1973, decadal count and measurement would provide growth comparison at all section points for 1963, 1953, 1943, and so forth back through time at 10-year intervals.

b. If desirable to compare tree growth at even chronological decades, decadal ring count also must begin at section circumference and proceed toward the pith. However, modification of procedure is necessary. For example, for trees cut in 1973, if tree growth

comparison is desirable at even decades, i.e., 1970, 1960, 1950, etc., the first multiple-ring count on each section from circumference must span three growth rings to reach an even decade.<sup>7/</sup> For remainder of rings to pith, decadal counts are taken. Sequential radial increment measurements are again made from the pith outward along each established radius.

c. If desirable to compare growth of trees at specific breast height ages, e.g., at 10-year intervals, a more complicated procedure of ring count and measurement (see footnote 2, p. 3) is necessary than has been described. Decadal counts and measurements for the breast height sections must begin at the *pith*. For example, where decadal ring measurements

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<sup>7/</sup> If the 1973 growth ring is present.

are to be taken, a ring number less than 10 will likely occur as a partial decadal count next to the circumference. The number nine or less will be used to begin ring counts from the circumference on all other sections including the stump. Sequential radial increment measurements again begin at the pith and continue toward the circumference for each radius.

For this paper, the first-described multiple-ring count method--all counts begin at the circumference of each section--is used. The computer program described herein was developed accordingly. Some modification of the program is necessary to produce alternate stem analysis information describing growth at even chronological decades or at specific breast-high age intervals. It should be carefully noted that regardless of selected multiple ring count approach, all sequential growth measurement information is obtained from cumulative multiple annual ring measurements *always* taken from the pith outward toward the circumference of each section. For our computer program, that procedure is necessary to provide growth data for a normal stem profile graph of height over radius.

Unless the tree was extremely out of round or the pith obviously was excessively off geometric center, as is sometimes found in trees on very steep slopes, only one selected radius was taken for sections where longest radius differed from shortest by 10 percent or less. Otherwise, at least two radii--the longest and one about 180° to the longest--were selected. Three radii, the longest and two others about 120° each side of the longest, were taken on stump sections. For our stem analysis studies, that system always resulted in acceptable profiles. Failure to select the proper radii for annual ring counts and measurements will result in unacceptable stem profiles (fig. 15, appendix I).

Successful utilization of stem analysis field and laboratory measurements to produce stem profiles depends on reasonably accurate average radii. There are several ways to determine the average radius (pith to perimeter) of a tree stem cross-section or disk. Because of limited finances and time, selection of "representative" radii was expedient. Most of our trees were old-growth specimens, and the common occurrence of annual ring growth aberrations caused by occluded rot, scars, knots, pitch pockets, etc., usually prevented actual designation of acceptable "true average radii"<sup>8/</sup> from pith to perimeter on stem section disks. Instead, radii were selected that were aberration-free and representative (ocularly) of the radial growth at each section point on the stem. For easy measurement of sequential radial growth from pith to perimeter and avoidance of inaccuracies caused by missing rings (Douglass 1928), the shorter radii from any section were avoided.

When more than one radius per section was measured, sequential increment measurements of each radius were reportioned (table 1) and a simple arithmetic average of each reportioned radial increment was calculated and coded for

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<sup>8/</sup> Radii derived from halving diameter tape measurements and accepting the small positive bias inherent with the diameter tape method (Matérn 1956).

keypunching (appendix I, fig. 12). Reproportioning was done by the equation:

$$RRIM = \frac{Dib/2}{TAR} \quad (RIM)$$

Where  $RRIM$  = Reproportioned sequential radial increment measure-

*Dib* = Diameter inside bark of section as determined by diameter tape

*TAR* = Total length of actual measured radius (representative radius)

*RIM* = Sequential increment measurement from representation

sentative radius.

Multiple radii were averaged with a desk calculator or by a simple program on a desk-top computer.

A more complicated method of averaging with the quadratic mean approach was

suggested by Matérn (1956). According to Matérn, the quadratic mean of several random radii at each section point provides an unbiased estimate of any area, convex or not, and is applicable to closures such as those projected by tree stem cross-sections. We used available reproportioned multiple radius data, and our resulting average radii differed little from those produced by the quadratic mean approach. The differences were small (usually second and third decimal place) because all measured radii were reproportioned to the section's average radius before they were averaged (table 1).

Reproportionment of sequential radial growth measurements for sections with a single radius is automatically completed by the computer program. Therefore, such sections can be coded and keypunched as measured.

Table 1.--Multiple radius computations for NF1, plot 75

Section: Stump

Single bark thickness: 1.30 inches

Section height above ground: 1.5 feet

Section ring count: 437 years

Section d.o.b.: 74.90 inches

Measured radial data			Reproportioned radial data			Average reproportioned radial data
Radius 1	Radius 2	Radius 3	Radius 1	Radius 2	Radius 3	
0.78	0.76	0.83	0.73	0.80	0.83	0.79
1.82	1.69	1.80	1.71	1.79	1.80	1.77
2.97	2.74	2.90	2.80	2.90	2.91	2.87
4.41	3.99	4.19	4.15	4.22	4.20	4.19
5.96	5.38	5.65	5.61	5.70	5.67	5.66
.	.	.	.	.	.	.
.	.	.	.	.	.	.
.	.	.	.	.	.	.
36.69	32.65	34.45	34.54	34.56	34.55	34.55
37.15	33.04	34.88	34.97	34.98	34.98	34.98
37.62	33.46	34.32	35.42	35.42	35.42	35.42
37.91	33.72	35.59	35.69	35.69	35.69	35.69
38.40	34.15	36.05	36.15	36.15	36.15	36.15

Production of stem profiles from nonreproportioned measurement data for sections with a single radius, together with those having averages of reproportioned multiple radii, is completed by the computer program described and presented in appendixes II and III. Should automatic reproportioning of all radii, both single and multiple, be desired, a revision of that program is required.

### RADIAL MEASUREMENTS, SEQUENTIAL RADIAL GROWTH DATA RECORDS, AND SECTION STORAGE

Where only one radius is required, no field counts or measurements need be taken. A selected or representative radius from a transverse section cut with a small chain saw can be taken from the field for later processing in the office or laboratory (fig. 7). For sections less than 10

inches in diameter, the complete disk should be collected because of difficulty in cutting a radial section.

For both permanent ring count and sequential radial growth records where complete disk sections cannot be taken, counts and measurements on sections requiring multiple radii must be completed in the field. Heavy clear plastic overlays (fig. 8) have been used successfully for permanent ring count and growth records. Douglass (1919) used a similar technique to obtain sequential radial growth records. He used "paper rubbings" for transcribing ring-growth information from transverse radial sections.

Prior to field use, fine parallel lines spaced one-half inch apart were drawn on the transparent plastic with a sharp round point such as a push pin or shortened dissection needle. After any radius on a section was established, counts were made



Figure 7.--Large transverse disk from sectioned noble fir with the representative radius removed.



Figure 8.--Tracing radial ring pattern on plastic overlay.

as previously described and decadal or other multiple ring marks were made on the wood with a *hard* sharp-pointed blue lead pencil. A moist surface provided darker and sharper blue pencil marks. For accuracy and uniformity, we recommend that all marks be made so that the edge of the blue pencil line coincides with the *outside* edge of the summer wood for each marked ring. Transcribing these marks to the fine parallel lines on a plastic overlay was relatively simple, again done with a sharp-pointed scribe. Where any radius was longer than a single line on the overlay, a second line, etc., with proper documentation was used for continuation. These plastic overlays were set aside for later checking and measurement and are available for other observations. Scribed marks on the clear plastic are easily seen with a dark-colored background under the plastic.

A transverse section of wood was also

collected, cut with a small chain saw; it contained the best representative radius from sections (stump, b.h., etc.) from which multiple radii were transcribed to plastic. These radial transverse sections were valuable for correcting any errors later encountered.

Identification of sections is extremely important. Aluminum flashing squares (such as those used for referencing and boundary marking during surveying)--with identification scribed by ballpoint pen--were found to be the most durable method of marking wood sections. They were firmly stapled adjacent to and not covering selected radius of each section top. Each section was identified with plot number, tree species, tree number, and stem section location; e.g., "P70 NF1 127.3" means plot 70, noble fir 1, 127.3 feet above stump. "Top" of each section was always identified.

Radial transverse sections and disks for each tree were packaged with fiber-glass tape. An identification tag bearing plot, tree number, species, and general location was attached to each package of radial transverse sections (fig. 9).

## Stem Analysis Laboratory and Computer Methods

Annual-ring counts and sequential radial growth measurements not completed in the field were made in the laboratory by the count plan selected. The sequential radial growth marks transcribed in the field to the plastic overlays also were measured according to the selected count plan, and the data were entered on a coding form (fig. 11, appendix I). Data on the coding forms were keypunched on standard 80-column ADP cards.

Sequential radial growth was measured

with a 24-inch machinist rule graduated to the nearest hundredth of an inch except where annual rings were closely spaced. For transverse sections with rings very close together, a dendrochronograph equipped with a traveling binocular zoom microscope was used (fig. 10), and sequential radial growth was measured to the nearest hundredth of a millimeter. To correspond with ruler-measured data for our studies, metric information was converted to inches.

For easier ring counts and measurements along representative radii, the wood surface on stem section disks or radial transverse sections was smoothed with a thin-bladed, chisel-edged, hobby-type razor-knife or was sanded with an electric sander. Sanding with very fine sandpaper usually was done only when narrow growth rings (about 40 or more per inch) were encountered. Douglass (1928) favored the razor-knife method of wood surface preparation over that of

Figure 9.--Radial transverse sections and disks packaged for laboratory examination. Tag identifies package of sections of white fir, tree number 1, from the Rogue River National Forest.

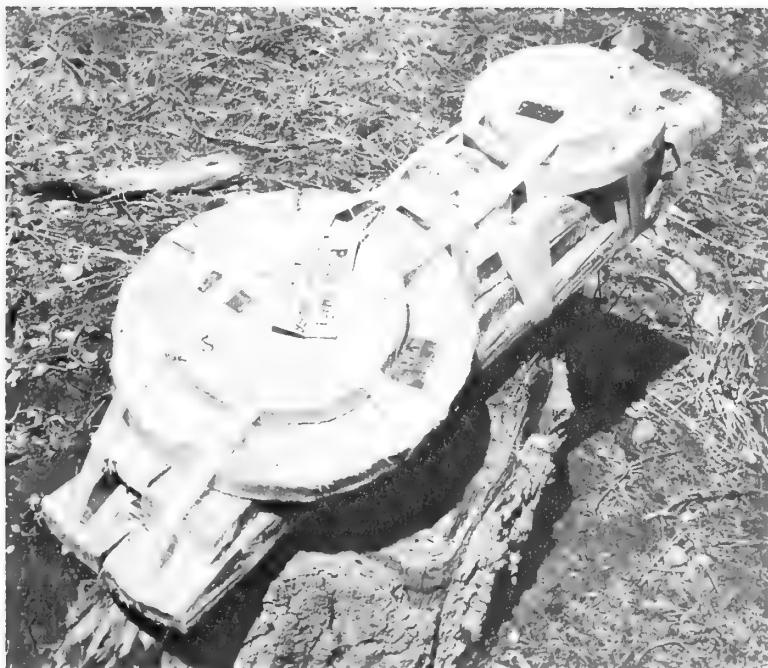




Figure 10.--A dendrochronograph was used to measure radial growth where annual rings were closely spaced.

sanding, and our work supported that opinion. To make the annual rings more distinct, we used water for most species. For resinous wood of pines and occasionally Douglas-fir, we found that kerosene or other light oil was the best agent for enhancing the annual rings. Sophisticated wood-staining techniques were unnecessary.

Where there was concern for radial shrinkage in the collected radial sections and transverse disks, the current year's or "green" radii were placed on the plastic overlays in the field. Two marks--pith center and section perimeter edge--were transcribed to these plastic overlays. Before laboratory ring counts and sequential radial growth measurements were taken, green dimensions were restored by soaking the collected specimens in water (Herman and DeMars 1970) for at least 24 hours, then draining them overnight. Radii of green sections that were correctly marked on the plastic

always corresponded closely to those of the water-restored sections. Ring intervals for these field-selected representative radii then were marked off and measured according to the selected count plan.

## COMPUTER PROGRAM FOR STEM ANALYSIS DATA

At least two previous programs using stem analysis data for computing and graphing tree growth are in existence (Brace and Magar 1968, Pluth and Cameron 1971). Both of these automated methods machine-plot derived tree growth parameters. Neither program provides a standard height-radius stem profile as provided in this paper. Both programs provide volume and basal area computations that could be adapted for use with our program.

Preparation for computer production of stem analysis data requires coding of the field and the laboratory data from stem disks and scribed plastic overlays. Figure 12, appendix I, is a stem analysis data code completed for "NF1, plot 75." From data sheets such as these, 80-column ADP cards were keypunched and verified. A computer was programmed to produce for each tree: (1) a stem analysis graph (fig. 13, appendix I) using reproportioned radial data and straight-line interpolated heights, (2) listing of reproportioned radial data corresponding to the stem analysis profile, (3) a set of ADP cards punched to contain the reproportioned data, (4) a height-age listing by the selected ring-count interval using straight-line interpolation, (5) a height-age graph of the original tree data, and (6) a set of ADP cards punched to contain the selected ring count interval height-age data.

Any or all of the previous items can be selected as output for an individual tree on a single run. These options are explained in appendix II, card type I.

## EDITING STEM ANALYSIS DATA USING THE COMPUTER PROGRAM

In actual practice, usually only the stem profile was plotted first to discover if any errors existed in the raw data. Such errors (figs. 14 and 15, appendix I) were readily determined and corrections were made to insure that the changes were correct. Following the production of an acceptable stem profile graph, the remaining computer program options were selected for completion. Data editing using the stem profile graph should be done cautiously because not all apparently eccentric profile graph lines are measurement errors. Some line aberrations can be caused by growth problems such as old stem breaks, forks, etc.

\* \* \* \*

A copy of the stem analysis program listing is in appendix III. Further information about the program may be obtained from the Pacific Northwest Forest and Range Experiment Station, P. O. Box 3141, Portland, Oregon 97208.

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## Appendix I

Table 2.--Noble fir and associated species felled and sectioned during stem analysis studies

Common name	Scientific name <sup>1/</sup>	Species ADP code
noble fir	<i>Abies procera</i> Rehd.	022
Douglas-fir <sup>2/</sup>	<i>Pseudotsuga menziesii</i> (Mirb.) Franco	202
Pacific silver fir	<i>Abies amabilis</i> (Dougl.) Forbes	011
western hemlock	<i>Tsuga heterophylla</i> (Raf.) Sarg.	263
mountain hemlock	<i>Tsuga mertensiana</i> (Bong.) Carr.	264
western white pine	<i>Pinus monticola</i> Dougl.	<sup>3/</sup> 119
grand fir <sup>2/</sup>	<i>Abies grandis</i> (Dougl.) Lindl.	015
western redcedar	<i>Thuja plicata</i> Donn.	254
subalpine fir	<i>Abies lasiocarpa</i> (Hook.) Nutt.	019
western larch	<i>Larix occidentalis</i> Nutt.	073
lodgepole pine	<i>Pinus contorta</i> Dougl.	108
Engelmann spruce	<i>Picea engelmannii</i> Parry	093
Shasta red fir <sup>2/</sup>	<i>Abies magnifica</i> var. <i>shastensis</i> Lemm.	021
ponderosa pine <sup>2/</sup>	<i>Pinus ponderosa</i> Laws.	122

<sup>1/</sup> Scientific names follow Elbert L. Little, Jr., Check list of native and naturalized trees of the United States (including Alaska). U.S. Department of Agriculture, Agriculture Handbook 41, 472 p., 1953.

<sup>2/</sup> Species associated with Shasta red fir felled and sectioned south of the known normal range of noble fir. Douglas-fir and grand fir (white fir) were sampled in both the noble fir range and Shasta red fir range.

<sup>3/</sup> Grand fir and white fir considered as single species for this phase of study--both coded "015."

STEM ANALYSIS DATA		Date felled	Initials	Sheet	of
Plot no.	Plot name	Date measured			
Plot no.	Tree no.	Species			
1	1	Plot Number			
2	2	Tree Number			
3	3	Species Code			
4	4	Diameter Breast Height			
5	5	Age at Breast Height			
6	6	Card Number			
7	7	Annual Ring Increment			
8	8	Number of Sections Including Tip			
9	9	Section Thickness			
10	10	St. Ht. Cumulative Height Above Stump			
11	11	Section Diameters Outside Bark			
12	12	Bank Thickness			
13	13	Age of Section			
14	14	Cumulative Annual Ring Measurement From Pith			
15	15	Cumulative Annual Ring Measurement From Pith @ B.H.			
16	16	Cumulative Annual Ring Measurement From Pith @ Stump			
17	17	Etc.			
18	18	Etc.			
19	19	Etc.			
20	20	Etc.			
21	21	Etc.			
22	22	Etc.			
23	23	Etc.			
24	24	Etc.			
25	25	Etc.			
26	26	Etc.			
27	27	Etc.			
28	28	Etc.			
29	29	Etc.			
30	30	Etc.			
31	31	Etc.			
32	32	Etc.			
33	33	Etc.			
34	34	Etc.			
35	35	Etc.			
36	36	Etc.			
37	37	Etc.			
38	38	Etc.			
39	39	Etc.			
40	40	Etc.			
41	41	Etc.			
42	42	Etc.			
43	43	Etc.			
44	44	Etc.			
45	45	Etc.			
46	46	Etc.			
47	47	Etc.			
48	48	Etc.			
49	49	Etc.			
50	50	Etc.			
51	51	Etc.			
52	52	Etc.			
53	53	Etc.			
54	54	Etc.			
55	55	Etc.			
56	56	Etc.			
57	57	Etc.			
58	58	Etc.			
59	59	Etc.			
60	60	Etc.			
61	61	Etc.			
62	62	Etc.			
63	63	Etc.			
64	64	Etc.			
65	65	Etc.			
66	66	Etc.			
67	67	Etc.			
68	68	Etc.			
69	69	Etc.			
70	70	Etc.			
71	71	Etc.			
72	72	Etc.			
73	73	Etc.			
74	74	Etc.			
75	75	Etc.			
76	76	Etc.			
77	77	Etc.			
78	78	Etc.			
79	79	Etc.			
80	80	Etc.			
81	81	Etc.			
82	82	Etc.			
83	83	Etc.			
84	84	Etc.			
85	85	Etc.			
86	86	Etc.			
87	87	Etc.			
88	88	Etc.			
89	89	Etc.			
90	90	Etc.			
91	91	Etc.			
92	92	Etc.			
93	93	Etc.			
94	94	Etc.			
95	95	Etc.			
96	96	Etc.			
97	97	Etc.			
98	98	Etc.			
99	99	Etc.			
100	100	Etc.			

Figure 11.--Stem analysis data code sheet.

STEM ANALYSIS DATA	Plot no.	75	Tree no.	1	Date felled	8/1/68	Initials	_____
Study no.	W61, w63	Plot name	Yellowjacket Creek	Species	Noble Fir	Date measured	8/12/68	Sheet 1 of 2
75	1	022	658	432	1211	15	30	214
	2		2494	2583	2640	394	573	754
	3		7490	6580	5410	269	2691	2711
	4		912	590	335	214	137	0
	5		130	157	18	118	95	105
	6		66	42	21	14	10	0
	7		437	432	415	399	381	374
	8		8	93	64	38	23	16
	9		9	79	23			0
	10		10	177	144			
	11		11	287	230	44		
	12		12	419	314	188		
	13		13	566	433	362	137	
	14		14	698	530	528	285	15
	15		15	831	642	619	446	245
	16		16	990	756	742	613	446
	17		17	125	844	830	728	591
	18		18	1246	924	910	829	709
	19		19	1294	1009	995	920	822
	20		20	1472	1087	1070	900	922
	21		21	1556	1163	1149	1073	1015
	22		22	1660	1214	1209	1134	1093
	23		23	1760	1284	1270	1211	1174
	24		24	1851	1366	1351	1295	1263
	25		25	1930	1457	1420	1371	1341
	26		26	2040	1527	1466	1421	1406
	27		27	2169	1621	1517	1479	1467
	28		28	2315	1698	1586	1542	1521
	29		29	2425	1779	1658	1602	1587
	30		30	2512	1833	1695	1637	1629
	31		31	2578	1901	1737	1700	1667
	32		32	2652	1998	1810	1749	1724
	33		33	2724	2086	1879	1806	1780
	34		34	2768	2161	1933	1866	1825
	35		35	2803	2208	1975	1909	1859

Figure 12.--Completed stem analysis data code sheet for noble fir 1, plot 75.

STEM ANALYSIS DATA Plot no. 75  
 Study no. W61, W63 Plot name Yellow

Tree no. 1  
Species Noble Fir  
Location Widjet Creek

Date felled 8/11/68 Initials THW  
Date measured 8/12/68 Sheet 2 of 2

Figure 1.2 (Cont'd.)--Completed stem analysis data code sheet for noble fir 1, Plot 75.

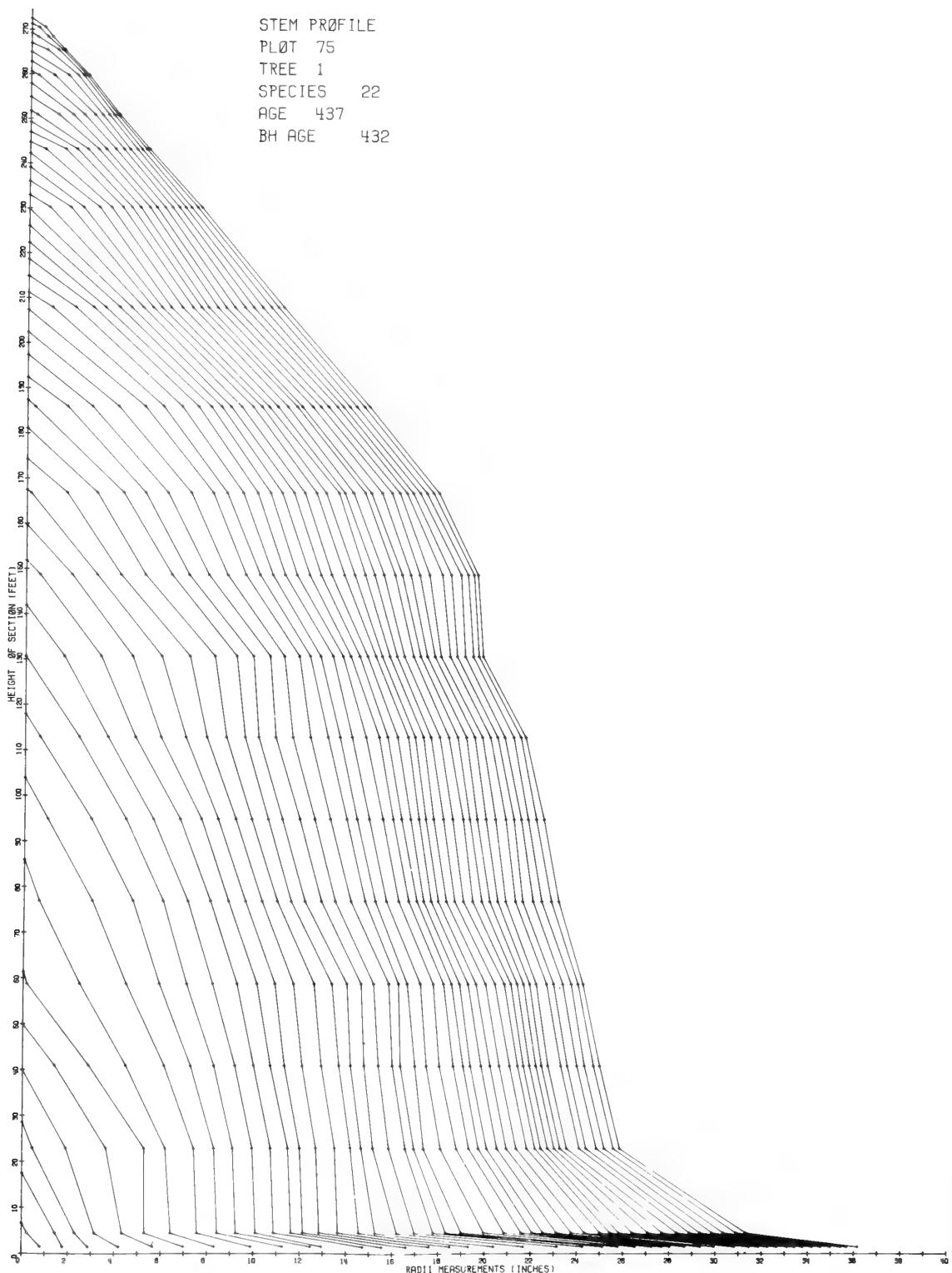


Figure 13.--Computer produced stem profile chart for noble fir 1, plot 75.

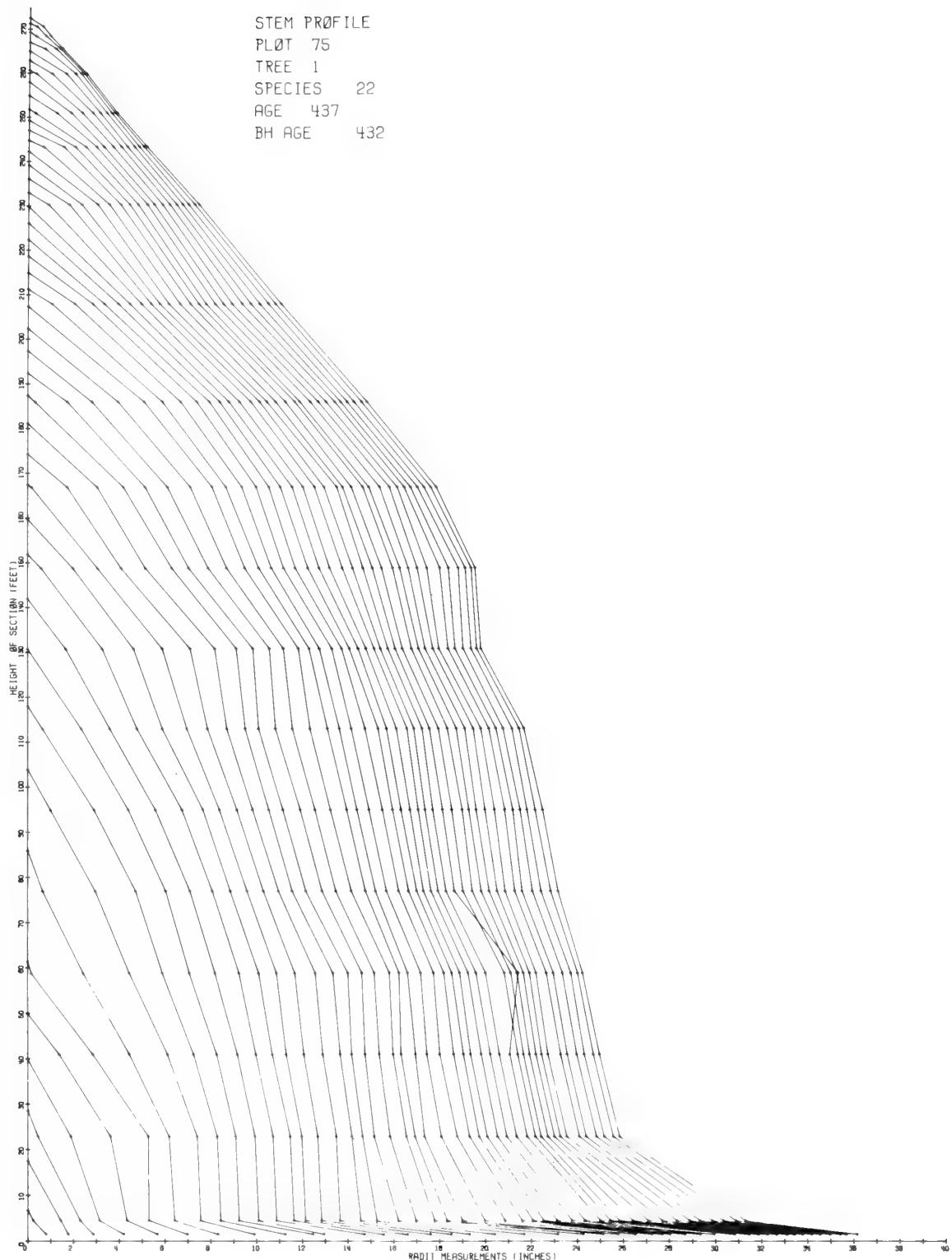


Figure 14.--Computer produced stem profile graph showing error in data.

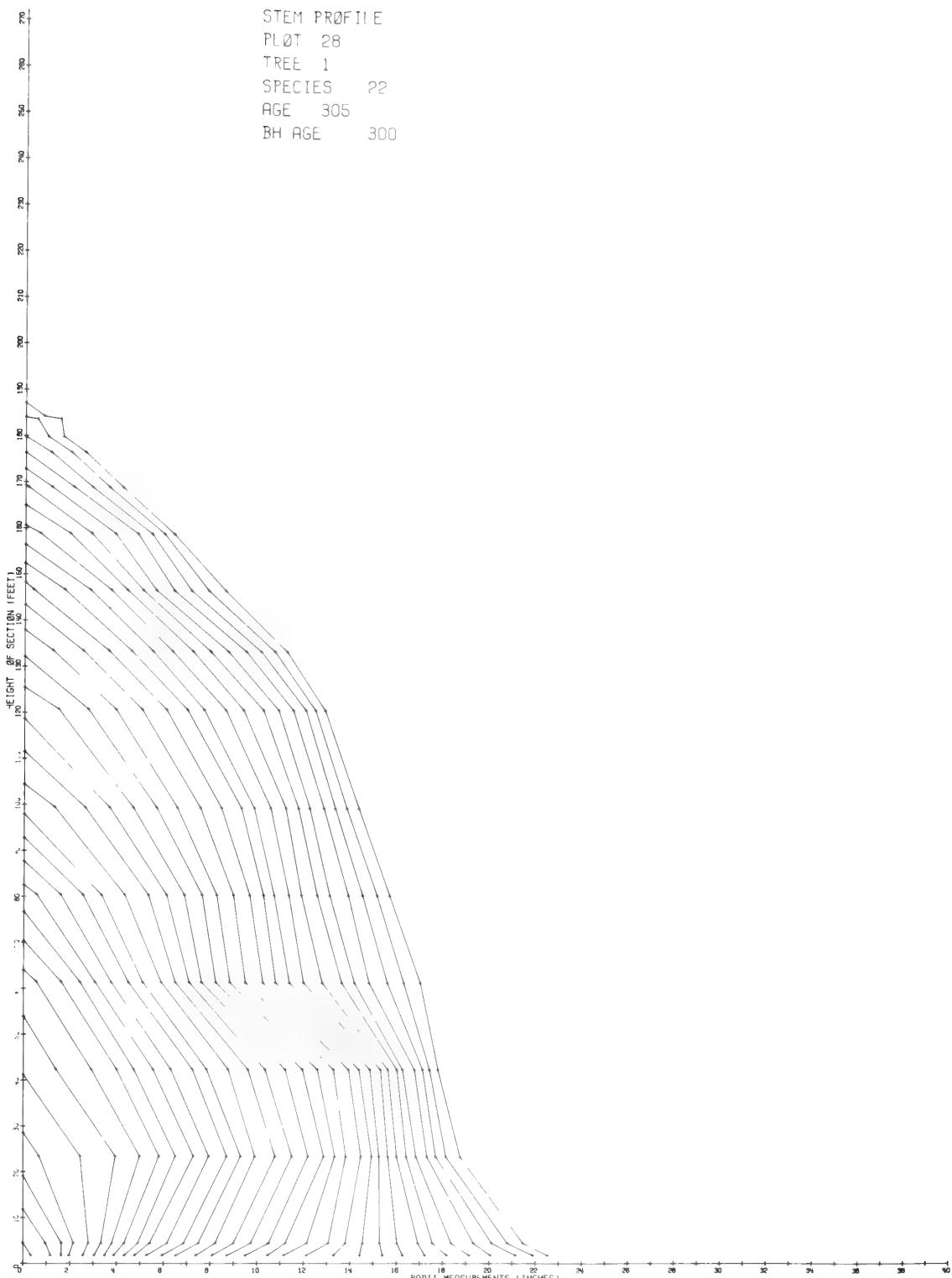


Figure 15.--Computer produced stem profile showing results of inadequate data measurements at lower stem section points.

## Appendix II

### Card Input Formats

With the exception of the "00" card, the program<sup>1/</sup> data input cards can be punched directly from the stem analysis data code sheets (figs. 11 and 12 of appendix I). Descriptive plot and miscellaneous tree information to be punched on the "00" card comes from various places in the original field notes. Transcription of that information into the following format is mandatory.

#### Card Type I--"00" Card

<u>Card columns</u>	<u>Implied decimal designation</u>	<u>Identification</u>	<u>Special notes</u>
1-3	XXX	Plot number	
4	X	Tree number	
5-7	XXX	Species code	Table 2, appendix I
8-11	XXX.X	D.b.h. (o.b.)	Inches
12-15	XXXX	Breast height ring count	
16-17	XX	Card number	Always "00"
18-19	XX	Number of sections taken for the tree	(Including tip, limit--30)
20	X	Ring count measurement interval (years)	1 = 10 yr 5 = 5 yr 3 = 1 yr
21-22	XX	Year cut	
23-24	XX	Crown class	Dominant and tallest on plot--11 Dominant--1 Codominant--2 Intermediate--3 Suppressed--4
25-28	XXX.X	Height to first live limb (feet)	Above average ground level
29-32	XXX.X	Height to live crown (feet)	Above average ground level
33-36	XXX.X	Clear length (feet)	Above average ground level
37-40	XXX.X	Crown length (feet)	Above average ground level

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<sup>1/</sup> Regardless of tree size or age, program is adaptable to data from 30 section points where the 30th section point is the tip having a diameter of "0" and a single bark thickness of "0." Also, program is limited to 80 incremental measurement intervals. Expressed in terms of stump age, program will accommodate an 80-year-old tree at 1-ring measurement intervals, a 400-year-old tree at 5-ring measurement intervals, or an 800-year-old tree at 10-ring measurement intervals.

Card Type I--"00" Card, continued

<u>Card columns</u>	<u>Implied decimal designation</u>	<u>Identification</u>	<u>Special notes</u>
41-45	XXXXX	Elevation (feet)	
46	X	Blank	
47	X	Aspect	Aspect codes Level - 0 North, northeast 1,2 East, southeast 3,4 South, southwest 5,6 West, northwest 7,8
48-50	XXX	Slope (percent)	
51-56	XXXXXX.X	Latitude north	Cols. 51-53 degrees Cols. 54-56 min
57-62	XXXXXX.X	Longitude west	Cols. 57-59 degrees Cols. 60-62 min
63-65	XXX	Preliminary noble fir site index	From PNW-119
66-69	XXX.X	Total tree height (feet)	<sup>2/</sup> Res. Note 1970 <sup>2/</sup>
70-74	XXXXX	Blank	
75	X	Card output of reportioned data	To suppress output, punch a "1"; otherwise leave blank.
76	X	Printed output of reportioned data	To suppress output, punch a "1"; otherwise leave blank.
77	X	Stem profile	To suppress output, punch a "1"; otherwise leave blank.
78	X	Card output of height-age data by the selected ring count interval	To suppress output, punch a "1"; otherwise leave blank.
79	X	Printed output of height-age data by the selected ring count interval	To suppress output, punch a "1"; otherwise leave blank.
80	X	Height-age plot of original tree data	To suppress output, punch a "1"; otherwise leave blank.

<sup>2/</sup> Donald J. DeMars, Francis R. Herman, and John F. Bell. Preliminary site index curves for noble fir from stem analysis data. USDA Forest Service Research Note PNW-119, 9 p., illus. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon, 1970.

Card Type II--Section Height Card

<u>Card columns</u>	<u>Implied decimal designation</u>	<u>Identification</u>	<u>Special notes</u>
1-3	XXX	Plot number	
4	X	Tree number	
5-7	XXX	Species	See ADP code table 2, appendix I
8-11	XXX.X	D. b. h. (o. b.)	Inches
12-15	XXXX	Breast height age	Years
16-17	XX	Card number	Card position in tree deck
18-19	XX	Number of sections	(Including tip) limit: 30 or less
20	X	Ring count measurement interval	1 = 10-yr interval 5 = 5-yr interval 3 = 1-yr interval
21-24	XXX.X	Stump height (ft)	Section 1
25-28	XXX.X	Height above the stump of breast height section	Section 2
29-32	XXX.X	Height above the stump of section 3	Section 3
33-36	XXX.X	Height above the stump of section 4	Section 4
.	.	.	.
.	.	.	.
.	.	.	.
77-80	XXX.X	Height above the stump of section 15	Section 15

Up to 15 section heights can be punched on one computer card, and the program can process up to 30 section heights for any one tree. The additional section heights are punched on a continuation card (same format as above) with section 16 height data entered in columns 21-24. It should be noted that the tip height measurement is considered one section. Columns 1 to 20 of the continuation card will be a duplicate of the previous card except for columns 16 and 17 which will contain the card's position number in the tree deck.

Card Type III--Section Diameter (Outside Bark) Card

For every section height, a corresponding diameter outside bark is needed (tip height diameter equals zero).

<u>Card columns</u>	<u>Implied decimal designation</u>	<u>Identification</u>	<u>Special notes</u>
1-15		(Same as section height card)	
16-17	XX	Card number	Card position in tree deck
18-20		(Same as section height card)	
21-24	XX.XX	D. o. b. of stump section	Section 1
25-28	XX.XX	D. o. b. of breast height section	Section 2
29-32	XX.XX	D. o. b. of section 3	Section 3
33-36	XX.XX	D. o. b. of section 4	Section 4
.	.	.	.
.	.	.	.
.	.	.	.
77-80	XX.XX	D. o. b. of section 15	Section 15

If the number of section heights (including tip height) exceeds 15, a continuation card will be necessary with the diameter outside bark of the 16th section entered in columns 21-24. The first 20 columns of the continuation card will be identical to the previous card except columns 16 and 17 will contain the card's position number in the tree deck.

### Card Type IV--Single Bark Thickness Card

For every section height a corresponding single bark-thickness is needed (tip height bark thickness equals zero).

<u>Card columns</u>	<u>Implied decimal designation</u>	<u>Identification</u>	<u>Special notes</u>
1-15		(Same as section height card)	
16-17	XX	Card number	Card position in tree deck
18-20		(Same as section height card)	
21-24	XX.XX	Single bark thickness of stump section	Section 1
25-28	XX.XX	Single bark thickness of breast height section	Section 2
29-32	XX.XX	Single bark thickness of section 3	Section 3
33-36	XX.XX	Single bark thickness of section 4	Section 4
.	.	.	.
.	.	.	.
.	.	.	.
77-80	XX.XX	Single bark thickness of section 15	Section 15

If the number of section heights (including tip height) exceeds 15, a continuation card will be necessary with the single bark thickness of the 16th section entered in columns 21-24. The first 20 columns of the continuation card will be identical to the previous card except columns 16 and 17 will contain the card's position number in the tree deck.

Card Type V--Section Ring Count

For every section height a corresponding section ring count is needed (tip height ring count equals zero).

<u>Card columns</u>	<u>Implied decimal designation</u>	<u>Identification</u>	<u>Special notes</u>
1-15		(Same as section height card)	
16-17	XX	Card number	Card position in tree deck
18-20		(Same as section height card)	
21-24	XXXX	Ring count of stump section	Section 1
25-28	XXXX	Ring count of breast height section	Section 2
29-32	XXXX	Ring count of section 3	Section 3
33-36	XXXX	Ring count of section 4	Section 4
.	.	.	.
.	.	.	.
.	.	.	.
77-80	XXXX	Ring count of section 15	Section 15

If the number of section heights (including tip height) exceeds 15, a continuation card will be necessary with the ring count of the 16th section entered in columns 21-24. The first 20 columns of the continuation card will be identical to the previous card except columns 16 and 17 will contain the card's position number in the tree deck.

### Card Type VI--Sequential Radial Increment Measurements Card

The remainder of the tree data deck consists of card type VI. The format for this card is:

<u>Card columns</u>	<u>Implied decimal designation</u>	<u>Identification</u>	<u>Special notes</u>
1-15		(Same as section height card)	
16-17	XX	Card number	Card position in tree deck
18-20		(Same as section height card)	
21-24	XX.XX	Radial increment measurements for stump section	Section 1
25-28	XX.XX	Radial increment measurements for stump section	Section 2
29-32	XX.XX	Radial increment measurements for stump section 3	Section 3
33-36	XX.XX	Radial increment measurements for stump section 4	Section 4
.	.	.	.
.	.	.	.
.	.	.	.
77-80	XX.XX	Radial increment measurements for stump section 15	Section 15

If the number of section heights (including tip height) exceeds 15, a continuation card will be necessary with the radial increment measurement of the 16th section entered in columns 21-24. The first 20 columns of the continuation card will be identical to the previous card, except columns 16 and 17 will contain the card's position number in the tree deck.

## Coding Format Layout Determination

Before card type VI can be punched, the radial increment data must be recorded on stem analysis data forms in a manner similar to that shown in figure 12 of appendix I, and as follows:

1. Calculate the total number of lines needed to record the stump radial measurements.

$$\text{Number of lines} = \frac{\text{Ring count of stump section (years)}}{\text{Ring count interval (years)}}$$

If the answer is not a whole number, round the answer up to the next whole number.

Figure 12 example:  $437/10 = 43.7$ . Next whole number; in this instance, 44 lines. Any decimal except .0 requires such rounding.

2. Calculate the number of lines needed to record the radial measurements for the 16th section (if there is a 16th section). If the 16th section is the tip, then one line is required to record the needed zero. Figure 12 example:  $93/10 = 9.3$ . Round up to 10 lines.
3. Calculate the total number of lines that will be needed for the tree. Total number of lines = number of lines used for heights, diameter, age, and bark + number of lines needed for stump section + number of lines needed for 16th section. Figure 12 example:  $8 + 44 + 10 = 62$  lines.
4. In columns 16 and 17 of the stem analysis data coding forms, number the lines consecutively up to the total number of lines calculated in item 3. Use additional forms if needed.
5. Calculate the line number where the first radial measurement of section 16 will be recorded.

Line number = Total number of lines - [(number of lines needed for section 16) - 1] \* 2 (asterisks used in computer coding format layout determination formulas mean "*multiplied by.*")

Figure 12 example:  $62 - (10-1) * 2 = 44$

6. Starting on the line calculated in item 5 and skipping every other line, record the radial increment measurements for the 16th section in columns 21-24 of the data forms. Last entry for section 16 should fall on line 62.
7. For all sections above the 16th section, calculate the line number where each section's first radial measurement will be recorded on the data forms. This calculation is as follows:

Line number for section "i" = Total number of lines - [(number of lines needed for section "i") - 1] \* 2

Where:

The number of lines needed for section "i" is calculated by the formula in item 1.

Figure 12 example for section 17: Line number =  $62 - [(7-1) * 2] = 50$

8. Starting on the line number calculated for section "i" in item 7, record section "i's" radial increment measurement data on every other line in the appropriate columns of the data forms.

9. Radial increment measurements for the stump section will begin on the line immediately following the last section ring count line (card type V) and will be recorded on consecutive lines until the first measurement of section 16 is encountered in columns 21-24 of the data form. When this occurs, subsequent radial measurements will be recorded on every other line until completion of the stump measurements.
10. For any "k" section 2 through 15, the beginning line number can be calculated by the following formula:  

$$\text{Line number} = \text{Total number of lines} - (\text{Lines required for 16th section}) - (\text{Lines required to record section "k"}) + 1$$
 Where the number of lines needed for section "k" is calculated by the formula in item 1.  
 Figure 12 example -- Section 2: Line number =  $62 - 10 - 44 + 1 = 9$   
 -- Section 3: Line number =  $62 - 10 - 42 + 1 = 11$
11. Record sections 2 through 15 beginning on the proper line number (as calculated in item 10) for the section being measured. *Remember* that all lines that have section 16 recorded on them will be skipped when recording sections 2 through 15. Because the above instructions are involved, we recommend that figure 12 of appendix I be studied for a full understanding of the proper format for the program input cards.

#### Program Output

Program output consists of punched card output as well as printed output. An example of printed output is shown in figures 16 and 17 of this appendix.

Two card decks are produced for each tree. One deck contains the rescaled sequential radial increment data and the other contains the age-height-site index information. The rescaled sequential radial increment deck has a format identical to the input card format.

The format for the age-height-site index output card is:

<u>Card columns</u>	<u>Implied decimal designation</u>	<u>Identification</u>	<u>Special notes</u>
1-2	XX	Study	
3-6	XXXX	Project	
7-10	XXXX	Species code	See table 2, appendix I
11-13	XXX	Plot number	
14-16	XXX	Tree number	
17-18	XX	Composite tree (normally 1)	1 = single tree, 2 or greater = composite tree used for averaging
19-22	XXXX	Stump age	
23-26	XXXX	Total breast height age	
27-30	XXXX	Site index at b. h., age 100	Blank if tree is less than 100 years at b. h.

<u>Card columns</u>	<u>Implied decimal designation</u>	<u>Identification</u>	<u>Special notes</u>
31-34	XXXX	Height above breast height	Interpolated values for each decadal ring count interval multiple
35-38	XXXX	Cumulative breast height age by successive decades	Decadal multiples of ring count measurement interval
39-46	XXXXXXXX	Blank	
47-49	XXX	Number of cards in this tree's site index deck	
50-80		Blank	

ST	PRO	SPE	PLOT	C	STUMP	B.H.	SITE	CUM				
									AGE	-4.5	AGE	CARDS
1	1	22	75	1	4.37	4.32	35.20	10.92	10	4.4		
		22	75	1	4.37	4.32	35.20	21.77	20	4.4		
		22	75	1	4.37	4.32	35.20	33.02	30	4.4		
		22	75	1	4.37	4.32	35.20	43.36	40	4.4		
		22	75	1	4.37	4.32	35.20	53.31	50	4.4		
		22	75	1	4.37	4.32	35.20	76.90	60	4.4		
		22	75	1	4.37	4.32	35.20	96.40	70	4.4		
		22	75	1	4.37	4.32	35.20	110.94	80	4.4		
		22	75	1	4.37	4.32	35.20	123.66	90	4.4		
		22	75	1	4.37	4.32	35.20	135.20	100	4.4		
		22	75	1	4.37	4.32	35.20	145.77	110	4.4		
		22	75	1	4.37	4.32	35.20	153.64	120	4.4		
		22	75	1	4.37	4.32	35.20	161.51	130	4.4		
		22	75	1	4.37	4.32	35.20	168.44	140	4.4		
		22	75	1	4.37	4.32	35.20	175.26	150	4.4		
		22	75	1	4.37	4.32	35.20	181.90	160	4.4		
		22	75	1	4.37	4.32	35.20	186.90	170	4.4		
		22	75	1	4.37	4.32	35.20	191.90	180	4.4		
		22	75	1	4.37	4.32	35.20	196.90	190	4.4		
		22	75	1	4.37	4.32	35.20	201.90	200	4.4		
		22	75	1	4.37	4.32	35.20	206.00	210	4.4		
		22	75	1	4.37	4.32	35.20	209.72	220	4.4		
		22	75	1	4.37	4.32	35.20	213.43	230	4.4		
		22	75	1	4.37	4.32	35.20	217.15	240	4.4		
		22	75	1	4.37	4.32	35.20	223.87	250	4.4		
		22	75	1	4.37	4.32	35.20	224.58	260	4.4		
		22	75	1	4.37	4.32	35.20	227.97	270	4.4		
		22	75	1	4.37	4.32	35.20	230.36	280	4.4		
		22	75	1	4.37	4.32	35.20	239.06	290	4.4		
		22	75	1	4.37	4.32	35.20	237.15	300	4.4		
		22	75	1	4.37	4.32	35.20	249.78	350	4.4		
		22	75	1	4.37	4.32	35.20	252.84	360	4.4		
		22	75	1	4.37	4.32	35.20	259.83	310	4.4		
		22	75	1	4.37	4.32	35.20	242.10	320	4.4		
		22	75	1	4.37	4.32	35.20	244.36	330	4.4		
		22	75	1	4.37	4.32	35.20	246.71	340	4.4		
		22	75	1	4.37	4.32	35.20	249.78	350	4.4		
		22	75	1	4.37	4.32	35.20	252.84	360	4.4		
		22	75	1	4.37	4.32	35.20	255.74	370	4.4		
		22	75	1	4.37	4.32	35.20	257.93	380	4.4		
		22	75	1	4.37	4.32	35.20	260.12	390	4.4		
		22	75	1	4.37	4.32	35.20	262.16	400	4.4		
		22	75	1	4.37	4.32	35.20	264.21	410	4.4		
		22	75	1	4.37	4.32	35.20	266.60	420	4.4		
		22	75	1	4.37	4.32	35.20	267.85	430	4.4		
		22	75	1	4.37	4.32	35.20	269.10	432	4.4		

Figure 16.--Height-age-site index written output.

TREE AND PLOT INFORMATION

08H= 65.8 , B.H. AGE= 432 CROWN CLASS= PRELIMINARY NOBLE FIR SITE INDEX=14.1 ELEVATION= 2903 ASPECT= 4 SLOPE= 10

HEIGHT TO FIRST LIVE LIRB=123.0      HEIGHT TO LIVE CROWN=123.0  
CLEAR LENGTH=123.0      CROWN LENGTH=149.6      TOTAL TREE HEIGHT= 272.6  
LATITUDE NORTH= 46 DEG 17.0 MIN      LONGITUDE WEST= 121 DEG 50.6 MIN

SPECTER - 23

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**Appendix III**  
**Stem Analysis Program Listing**

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PROGRAM NOBLE (INPUT,OUTPUT,PUNCH,TAPE8,TAPE5=INPUT,TAPE6=OUTPUT,
1TAPE7=PUNCH)
  DIMENSION HT(31),DIA(31),BT(31),IAGE(31),RADII(80,31),AGAS(31),
1AGABH(31),HTABH(31),HTTYI(80),IP(31),CRAD(80),RESCL(31,80),IRL(31,
280),KHT(80),JH(80),JD(80),JB(80)
3,XAX1(3),XAX2(3),YAX1(3),YAX2(3),BUF(2000),
4CHT(31)
  DATA YAX1 /30H HEIGHT OF SECTION (FEET) /
  DATA YAX2 /30H TOTAL HEIGHT OF TREE (FEET) /
  DATA XAX1 /30H RADII MEASUREMENTS (INCHES) /
  DATA XAX2 /30H AGE AT STUMP (YEARS) /
  ISKIP=0
  IF(ISKIP.EQ.1) GO TO 794
  CALL PLOTS(BUF,2000,8)
  CALL SYMBOL (0.,0.,.05,3,0.0,-1)
  CALL PLOT (2.,1.,-3)
794 CALL ZSUPRS
  CALL FZSUPR
  ISKIP=1
  I CONTINUE
C
C  READ *00* CARD
C
  READ(5,1572)IHP,IHT,IHS,IHDBH,JX,IHC,IHSEC,IHAI,YCUT,CRL_,Z1,Z2,Z3
1,Z4,Z5,Z6,Z7,Z8,ELEV,ASP,HSLOP,NLAT,NLONG,PNFSI,NERHT,ISCRD,
2ISFNT,ISSPT,IHACRD,IHAPNT,IHAPT
1572 FORMAT(I3,I1,I3,2I4,2I2,I1,F2.0,F2.0,4(A3,A1),F5.0,F2.0,F3.0,2I6,
1A3,I4,5X,6I1)
  IF(EOF,5)9000,88
  88 CONTINUE
  YYCUT=1900.+YCUT
C
C  ZERO ARRAYS
C
  DO 134 NAO=1,80
  DO 136 NAP=1,31
  HT(NAP)=DIA(NAP)=BT(NAP)=AGAS(NAP)=AGABH(NAP)=HTABH(NAP)=0.
  IAGE(NAP)=IP(NAP)=0
  RADII(NAO,NAP)=RESCL (NAP,NAO)=0.0
  IRL(NAP,NAO)=0
  HTTYI(NAO)=CRAD(NAO)=0.0
  KHT(NAO)=JH(NAO)=JD(NAO)=JB(NAO)=0
136 CONTINUE
134 CONTINUE
C
C  READ HEIGHTS OF SECTIONS
C
  READ(5,1000)IPLCT,ITREE,ISP,DBH,IA,ISEC,IAI,(HT(I),I=1,15)
1000 FORMAT(I3,I1,I3,F4.1,I4,2X,I2,I1,15F4.1)
  IF(ISEC.GT.15)2,3
  2 READ(5,1001)(HT(I),I=16,30)
1001 FORMAT(20X,15F4.1)

```

```

C      READ DIAMETERS OUTSIDE BARK OF SECTIONS
C
 3 READ(5,1002)(DIA(J),J=1,15)
1002 FORMAT(20X,15F4.2)
  IF (ISEC.GT.15)4,5
 4 READ(5,1002)(DIA(J),J=16,30)
C
C      READ BARK THICKNESS (SINGLE BARK THICKNESS)
C
 5 READ(5,1002)(BT(K),K=1,15)
  IF (ISEC.GT.15)6,7
 6 READ(5,1002)(BT(K),K=16,30)
C
C      READ SECTION RING COUNT
C
 7 READ(5,1003)(IAGE(L),L=1,15)
1003 FORMAT(20X,15I4)
  IF (ISEC.GT.15)8,9
 8 READ(5,1003)(IAGE(L),L=16,30)
 9 IF (IAI.EQ.1)XINCR=10.
  IF (IAI.EQ.5)XINCR=5.
  IF (IAI.EQ.3)XINCR=1.
  XAGE=IAGE(1)

C      READ MEASURED RADII OF SECTIONS
C
  JAC=XAGE/XINCR
  EXST=XAGE-(JAC*XINCR)
  IF (EXST.GT.0)JAC=JAC+1
  JAB=IAGE(16)/XINCR
  EXTRA=IAGE(16)-(JAB*XINCR)
  IF (EXTRA.GT.0)JAB=JAB+1
  NNON=JAC-JAB
  DO 10 M=1,80
  READ(5,1004)CHECK,(RADII(M,N),N=1,15)
1004 FORMAT(15X,F2.0,3X,15F4.2)
  IF (CHECK.EQ.99.) GO TO 100
  IF (ISEC.GT.15)11,10
 11 IF (M.GT.NNON)71,10
 71 READ(5,1004)CHECK,(RADII(M,N),N=16,30)
  IF (CHECK.EQ.99.) GO TO 100
 10 CONTINUE

C      CALCULATE NUMBER OF CARDS
C
 100 CARDS=XAGE/XINCR
  ICARD=CARDS
  XPAGE=IAGE(2)
  CRDS=XPAGE/XINCR
  ICRDS=CRDS
  IF (CRDS-ICRDS)138,138,139
139 ICRDS=ICRDS+1
138 IF (CARDS-ICARD)13,13,12
 12 ICARD=ICARD+1

```

```

C
C      CALCULATE AGE OF TREE AT A GIVEN HEIGHT ABOVE STUMP
C      AND BREAST HEIGHT
C
13 DO 14 IJ=1,ISEC
  IIJ=IJ+1
  AGAS(IJ)=IAGE(1)-IAGE(IJ)
  AGABH(IJ)=IAGE(2)-IAGE(IIJ)
C
C      CALCULATE HEIGHT ABOVE BREAST HEIGHT
C
  HTABH(IJ)=HT(IIJ)-HT(2)
14 CONTINUE
C
C      CALCULATE HEIGHTS ABOVE BREAST HEIGHT AT SELECTED YEAR INTERVALS.
C
  NOSEC=1
  IY=XINCR+.05
  NX=IAGE(2)/IY+1
  AXL=NX*IY- IAGE(2)
  IF(AXL.EQ.IY) NX=NX-1
  DO 15 IK=1,NX
  IF(IK.EQ.NX) GO TO 16
  COAGE=XINCR*IK
784 IF(COAGE.GT.AGABH(NOSEC)) 782,783
782 NOSEC=NOSEC+1
  GO TO 784
783 HTINT=HTABH(NOSEC)-HTABH(NOSEC-1)
  AGINT=AGABH(NOSEC)-AGABH(NOSEC-1)
  DIF=COAGE-AGABH(NOSEC-1)
  HTADD=(DIF/AGINT)*HTINT
  HTTYI(IK)=HTABH(NOSEC-1)+HTADD
  GO TO 115
16 HTTYI(IK)=HTABH(ISEC-1)
115 KHT(IK)=HTTYI(IK)+.5
15 CONTINUE
C
C      CALCULATE RESCALE OF RADII FOR INDIVIDUAL SECTIONS
C
  DO 17 ILL=1,ISEC
  IF(ILL.EQ.ISEC) GO TO 17
20 DO 19 IXD=1,ICARD
  IC=ICARD
  IP(ILL)=ICARD
  CRAD(ILL)=(DIA(ILL)-2.*BT(ILL))/2.
  RESCL(ILL,IXD)=(CRAD(ILL)/RADII(IC,ILL))*RADII(IXD,ILL)
19 IRL(ILL,IXD)=RESCL(ILL,IXD)*100.+.
5
17 CONTINUE
  IF(IHAPNT.GT.0)GO TO 1601
  WRITE(6,1102)
1102 FORMAT(1HI,54X,3HCUM/24X,35HC STUMP B.H. SITE HEIGHT B.H. /
  173H ST PRO SPE PLOT TREE T AGE AGE -4.5 -4.5 AGE
  2  CARDS  /  )
1601 CONTINUE
  DO 23 KIX=1,IC
  MAGE=KIX*XINCR
  IF(MAGE.GT.IAGE(2))MAGE=IAGE(2)

```

C PUNCH OUT SITE INDEX CARD

C  
NS=0  
SKKHER=HTTYI(10)  
IF(IAGE(2).LT.100)SKKHER=0.  
KKHER=KHT(10)  
IF(IAGE(2).LT.100)KKHER=0  
IF(IHACRD.GT.0)GO TO 1602  
WRITE(7,1100)NS,ISP,IPLOT,ITREE,IAGE(1),IAGE(2),KKHER, KHT(KIX),  
IMAGE,ICRDS  
1100 FORMAT(2H 1,2I4,2I3,2H 1,5I4,8X,I3)  
1602 CONTINUE  
IF(IHAPNT.GT.0)GO TO 1603  
1103 WRITE(6,1101)NS,ISP,IPLOT,ITREE,IAGE(1),IAGE(2),SKKHER, HTTYI(KI  
IX),MAGE,ICRDS  
1101 FORMAT(2H 1,4I5,3H 1,I5,I6,2F8.2,I6,8X,I6)  
1603 CONTINUE  
IF(MAGE.EQ.IAGE(2)) GO TO 22  
23 CONTINUE  
22 CONTINUE

C WRITE AND PUNCH OUT INFORMATION ON RESCALE

C  
HERHT=NERHT\*.1  
HLONG=NLONG\*.1  
HLAT=NLAT\*.1  
DHDBH=IHD8H\*.1  
ZLONG=NLONG\*.001  
ZLAT=NLAT\*.001  
JLON=ZLONG  
JLAT=ZLAT  
ZLONG=JLON\*100.0  
ZLAT=JLAT\*100.0  
ZLATM=HLAT-ZLAT  
ZLONGM=HLONG-ZLONG  
HLAT=JLAT  
HLONG=JLON  
IF(ISPNT.GT.0)GO TO 1604  
WRITE(6,1573)DHDBH,JX,CRL, Z1,Z2,Z3,Z4,PNFSI,Z5,Z6,Z7,Z8,HERHT,ELE  
IV,ASP,HSLOP,HLAT,ZLATM,HLONG,ZLONGM  
1573 FORMAT(1H1,42X,28HTREE AND PLOT INFORMATION //5X,4HD3H=,F5.1,  
15X, 9H8.H. AGE=,I4,5X,12HCROWN CLASS=,F3.0,5X,26HHEIGHT TO FIRST L  
2IVE LIMB=,A3,1H.,A1,5X,21HHEIGHT TO LIVE CROWN=,A3,1H.,A1//5X,33HP  
3RELIMINARY NOBLE FIR SITE INDEX=,A3,16X,13HCLEAR LENGTH=,A3,1H.,A1  
4,5X,13HCROWN LENGTH=,A3,1H.,A1,5X,18HTOTAL TREE HEIGHT=,F6.1//  
55X,10HELEVATION=,F5.0,5X,7HASPECT=,F3.0,5X,6HSLOPE=,F4.0,1H%,5X,15  
6HLATITUDE NORTH=,F4.0,4H DEG,F6.1,23H MIN LONGITUDE WEST=,F4.0,  
74H DEG,F6.1,4H MIN//)  
WRITE(6,1103)ISP,IPLOT,ITREE,(HT(I),I=1,21),(DIA(J),J=1,21),(BT(K)  
1,K=1,21),(IAGE(KRB),KRB=1,21)  
1103 FORMAT( 54X,9HSPECIES =,I4/47X,9HPLOT NO.,I4,4X,9HTREE NO.,I3  
1//7X,8HST.HT ++,6X,21HDISTANCE FROM STUMP,32X,20HDISTANCE FROM  
2STUMP/7X,F6.1,1X,20F6.1,1X  
3 /IX,132(IH+)/IX,EHDIA OR,F6.1,1X,20F6.1/IX,6HBARK ,F6.2,1X,  
420F6.2/IX,132(IH+)/4H AGE,3X,I6,1X,20I6)

```

1604 CONTINUE
  DO 41 IV=1,ISEC
    JH(IV)=HT(IV)*10.+.5
    JD(IV)=DIA(IV)*100.+.5
  41 JB(IV)=BT(IV)*100.+.5
  KNC=1
  KDBH=DBH*10.+.5
  IF(ISCRD.GT.0)GO TO 49
  WRITE(7,1572)IHP,IHT,IHS,IHDBH,JX,IHC,IHSEC,IHAI,YCUT,CR_L,Z1,Z2,Z
  I3,Z4,Z5,Z6,Z7,Z8,ELEV,ASP,HSLOP,NLAT,NLONG,PNFSI,NERHT
  WRITE(7,1105)IP_0T,ITREE,ISP,KDBH,IA,KNC,ISEC,IAI,(JH(KV),KV=1,15)
1105 FORMAT(I3,I1,I3,2I4,2I2,I1,15I4)
  IF(ISEC.GT.15)GO TO 42
  GO TO 43
  42 KNC=KNC+1
  WRITE(7,1105)IP_0T,ITREE,ISP,KDBH,IA,KNC,ISEC,IAI,(JH(KV),KV=16,30
  1)
  43 KNC=KNC+1
  WRITE(7,1105)IP_0T,ITREE,ISP,KDBH,IA,KNC,ISEC,IAI,(JD(KW),KW=1,15)
  IF(ISEC.GT.15) GO TO 44
  GO TO 45
  44 KNC=KNC+1
  WRITE(7,1105)IP_0T,ITREE,ISP,KDBH,IA,KNC,ISEC,IAI,(JD(KW),KW=16,30
  1)
  45 KNC=KNC+1
  WRITE(7,1105)IP_0T,ITREE,ISP,KDBH,IA,KNC,ISEC,IAI,(JB(KX),KX=1,15)
  IF(ISEC.GT.15) GO TO 46
  GO TO 47
  46 KNC=KNC+1
  WRITE(7,1105)IP_0T,ITREE,ISP,KDBH,IA,KNC,ISEC,IAI,(JB(KX),KX=16,30
  1)
  47 KNC=KNC+1
  WRITE(7,1105)IPLOT,ITREE,ISP,KDBH,IA,KNC,ISEC,IAI,(IAGE(KS),KS=1,
  115)
  IF(ISEC.GT.15) GO TO 48
  GO TO 49
  48 KNC=KNC+1
  WRITE(7,1105)IPLOT,ITREE,ISP,KDBH,IA,KNC,ISEC,IAI,(IAGE(KS),KS=16,
  130)
  49 IADI=IAGE(1)/XINCR
  LOV=IAGE(1)-(XINCR*IADI)
  IF(LOV.EQ.0)IADI=IADI-1
  IAD2=IADI
  DO 24 IPOJ=1,ICARD
    IHIST=YYCUT-(IADI*XINCR)
    IADI=IADI-1
    IF(ISFNT.GT.0)GO TO 1605
    WRITE(6,1104)IHIST,(RESCL(IB,IPOJ),IB=1,21)
1104 FORMAT(I5,2X,F6.2,1X,20F6.2)
1605 CONTINUE
  KNC=KNC+1
  IF(KNC.GT.98)KNC=98
  IF(ISCRD.GT.0)GO TO 24
  WRITE(7,1105)IP_0T,ITREE,ISP,KDBH,IA,KNC,ISEC,IAI,(IRL(IG,IPOJ),IG
  I=1,15)

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IF(ISEC.GT.15) GO TO 51
GO TO 24
51 IF(IRL(16,IPOJ).GT.0) GO TO 52
GO TO 24
52 KNC=KNC+1
IF(KNC.GT.98)KNC=98
WRITE(7,1105)IPLOT,ITREE,ISP,KDBH,IA,KNC,ISEC,IAI,(IRL(IG,IPOJ),IG
I=16,30)
24 CONTINUE
IF(ISEC.GT.21) GO TO 53
GO TO 8787
53 CONTINUE
IF(IISPNT.GT.0)GO TO 8787
WRITE(6,1107)ISP,IPLOT,ITREE,(HT(I),I=22,30),(DIA(J),J=22,30),(BT(
IK),K=22,30),(IAGE(KRB),KRB=22,30)
1107 FORMAT(1H1,53X,9HSPECIES =,I4/47X,9HPLOT NO.,I4,4X,9HTREE NO.,I3
1,4X,9HCONTINUED//13X,21HDISTANCE FROM STUMP,32X,21HDISTANCE FRO
2M STUMP/13X,9F6.1/1X, 67(IH+)/1X,6HDIA 0B,6X,9F6.1/1X,61BARK ,6X
3,9F6.2/1X,67(IH+)/4H AGE,9X,9I6)
DO 54 IU=1,ICARD
IHIST=YYCUT-(IAD2*XINCR)
IAD2=IAD2-1
IF(RESCL(22,IU).EQ.0.0) GO TO 54
WRITE(6,1108)IHIST,(RESCL(JU,IU),JU=22,30)
1108 FORMAT(I5,8X,9F6.2)
54 CONTINUE
8787 CONTINUE
IF(ISSPT.GT.0)GO TO 1609
YINK=10.
IF(IA1.EQ.3)YINK=5.0
XINK=2.0
IF(IAI.EQ.3)XINK=1.0
CALL AXIS(0.0,0.0,YAX1,30,27.5,90.0,0.0,YINK,10.,-1)
CALL AXIS(0.0,0.0,XAX1,-30,20.0,0.0, 0.0,XINK,20.,-1)
SPI=ISP
TREEI=ITREE
PLOTI=IPLOT
SSTAGE=IAGE(1)
CALL SYMBOL(5.0,27.0,.25,12HSTEM PROFILE,0.0,12)
CALL SYMBOL(5.0,26.5,.25,4HPLOT,0.0,4)
CALL NUMBER(6.25,26.5,.25,PLOTI,0.0,-1)
CALL SYMBOL(5.0,26.0,.25,4HTREE,0.0,4)
CALL NUMBER(6.25,26.0,.25,TREEI,0.0,-1)
CALL SYMBOL(5.0,25.5,.25,7HSPECIES,0.0,7)
CALL NUMBER(7.25,25.5,.25,SPI,0.0,-1)
CALL SYMBOL(5.0,25.0,.25,3HAGE,0.0,3)
CALL NUMBER(6.25,25.0,.25,SSTAGE,0.0,-1)
CALL SYMBOL(5.0,24.5,.25,6HBH AGE,0.0,6)
CALL NUMBER(7.25,24.5,.25,XPAGE,0.0,-1)

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C
C      CALCULATE HEIGHT BETWEEN SECTIONS FOR STEM PROFILES
C      AND PLOT STEM PROFILE
C
DO 445 IHER=1,80
DO 444 IREX=1,31
      CHT(IREX)=HT(1)+HT(IREX)
      IF(RESCL(1,IHER).EQ.0.0) GO TO 455
      IF(IREX.EQ.1) CHT(1)=HT(1)
      AXISH=CHT(IREX)/YINK
      IF(RESCL(IREX,IHER).LE.0.0) 447,448
447  DIFFA=IAGE(IREX-1)-IAGE(IREX)
      DIFFH=CHT(IREX)-CHT(IREX-1)
      ISA=IAGE(1)/XINCR
      DA=IAGE(1)-(ISA*XINCR)
      IF(DA.EQ.0.0) 641,642
642  SA=DA+(IHER-1)*XINCR
      GO TO 449
641  SA=(IHER)*XINCR
449  ANOM=SA-AGAS(IREX-1)
      AXISH=((ANOM/DIFFA)*DIFFH)+CHT(IREX-1))/YINK
      AXISR=0.0
      CALL SYMBOL(AXISR,AXISH,.05,3,0.0,-2)
      GO TO 445
448  IF(AXISH.GT.27.5) GO TO 455
      AXISR=RESCL(IREX,IHER)/XINK
      IF(AXISR.GT.20.0) GO TO 455
      IF(IREX.EQ.1) 451,452
451  CALL SYMBOL(AXISR,AXISH,.05,3,0.0,-1)
      GO TO 444
452  CALL SYMBOL(AXISR,AXISH,.05,3,0.0,-2)
444  CONTINUE
445  CONTINUE
C
C      PLOT OUT HEIGHT OVER AGE GRAPHS
C
455  CONTINUE
      CALL ADVANZ(44)
      CALL PLOT(0.0,0.0,19)
1609 CONTINUE
      IF(IHAPT.GT.0) GO TO 1
      YINK=10.
      IF(IAI.EQ.3) YINK=5.0
      XINK=25.0
      IF(IAI.EQ.3) XINK=5.0
      CALL AXIS(0.0,0.0,YAX2,30, 27.5,90.0,0.0,YINK,10.0,-1)
      CALL AXIS(0.0,0.0,XAX2,-30,21.0, 0.0,0.0,XINK,10.0,-1)
      CALL SYMBOL(5.0,26.5,.25,4HPLOT,0.0,4)
      CALL NUMBER(6.25,26.5,.25,PLOTI,0.0,-1)
      CALL SYMBOL(5.0,26.0,.25,4HTREE,0.0,4)
      CALL NUMBER(6.25,26.0,.25,TREEI,0.0,-1)
      CALL SYMBOL(5.0,25.5,.25,7HSPECIES,0.0,7)
      CALL NUMBER(7.25,25.5,.25,SPI,0.0,-1)
      CALL SYMBOL(5.0,25.0,.25,3HAGE,0.0,3)
      CALL NUMBER(6.25,25.0,.25,SSTAGE,0.0,-1)

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```
CALL SYMBOL (5.0,24.5,.25,6HBH AGE,0.0,6)
CALL NUMBER (7.25,24.5,.25,XPAGE,0.0,-1)
DO 453 IREG=1,31
XP=AGAS(IREG)/XINK
YP=CHT(IREG)/YINK
IF(AGAS(IREG).GT.525) GO TO 456
IF(IAGE(IREG).LE.0.AND.HT(IREG).LE.0.0) GO TO 456
IF (XP.GT.21.0) GO TO 456
IF (YP.GT.28.0) GO TO 456
CALL SYMBOL(XP,YP,.05,3,0.0,-1)
453 CONTINUE
456 CALL ADVANZ(44)
CALL PLOT(0.0,0.0,19)
GO TO 1
9000 CONTINUE
CALL PLOT (22.0,0.0,-3)
CALL PLOT(0,0,999)
986 STOP
END
```



Herman, Francis R., Donald J. DeMars, and Robert F. Woollard  
1975. Field and computer techniques for stem analysis of coniferous forest trees. USDA For. Serv. Res. Pap. PNW-194, 51 p., illus. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

Presents step-by-step instructions for stem analysis field and computer techniques which are adaptable to trees up to 800 years old. Stem profiles, height-age graphs, cards, and data lists are produced by the computer for any conifer for which growth information is to be analyzed.

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2. Developing and evaluating alternative methods and levels of resource management.
3. Achieving optimum sustained resource productivity consistent with maintaining a high quality forest environment.

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